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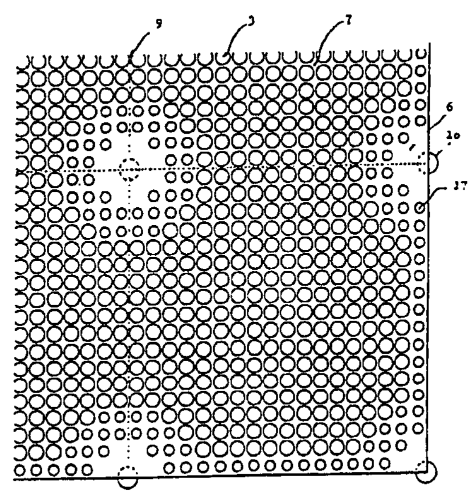
(54) Title: PLANE HOLLOW REINFORCED CONCRETE FLOOR WITH TWO-DIMENSIONAL STRUCTURE

(57) Abstract

The invention presents a technique to development of plane hollow reinforced concrete floor slabs with two-dimensional structure. Constructions developed by this technique will widely and with considerable profit replace conventional floor structures. The technique makes it possible to chose higher strength and stiffness, less volume of materials, greater flexibility, better economy or an arbitrary combination of these gains. The technique makes it possible to create a total balance between bending forces, shear forces and stiffness (deformations), so that all design conditions can be fully optimized at the same time. The technique presents a distinct minimized construction, characterized by the ability that the concrete can be placed exactly where it yields maximum capacity. The technique offers unusual profits compared with the conventional compact two-way reinforced slab structure: less volume of materials (concrete 40-50 %, steel 30-40 %); 100-150 % higher strength; up to 200 % higher span. The technique is suitable for both in situ works and for prefabrication.



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PLANE HOLLOW REINFORCED CONCRETE FLOORS WITH TWO-DIMENSIONAL STRUCTURE.

THE INVENTION relates to plane hollow reinforced concrete floors with two-dimensional structure and span in arbitrary direction.
The present floor structure is 1.part of a complete construction system developed for increased flexibility and large beamless span.

THE CONVENTIONAL TECHNIC

and the weakness of concrete floor structures is assumed well known.
Concrete floor structures have one fault.
The dead load is usually 2-4 times as heavy as the useful carrying capacity.
This situation has coursed numerous attempts to make the construction less heavy, mostly through creating some kind of internal cavity space.
Yet, no one has ever succeeded finding a general solution of the problem.
To obtain static and practical relevans a large number of conflicting conditions necessarily must be fulfilled at the same time, which is never approximately achieved.
All serious previous attempts therefore have been related to the simpel one-dimensional structure (span in one direction) rather than the much more complex two-dimensional structure (span in arbitrary direction).
The two constructions have quite different static function and can not be compared.

FLOORS WITH ONE-DIMENSIONAL STRUCTURE

are since the 1950'es fully developed through the the prefabricated and prestressed hollow concrete element, where the hollow space profil are made by monolitic concreting around steel pipes, wich are drawn out of the element after cementation leaving empty tubes inside the concrete.
The construction achieves maximum bearing strength corresponding to the concrete volume.
However, the construction can only be made as a prefabricated element. and the bearing capacity exists only in one direction.
This weakness locks the whole building construction in a firm, rigid system because the construction widely must be adapted to the floor elements.
The building system suffers from the necessity of bearing walls or beams and offers no really flexibility.

Prior to the technics of today it was known embedding pipes of sheet metal and the like.

From DE 2.116.479 (Hans Nyffeler apr.1970) it is suggested to convert the mentioned pipes to balls of lightweight materials (like a row of pearls), whereby shortning on the site of prefabricated pipes could be avoided. The ball lines are suggested made by boring holes through the middle of the balls and hang up the balls on a steel bar through the bore holes. The bar itself with the balls are to be hanged up in bent bars free of the reinforcement.

The idea suffers from several serious faults, which make the concept quite unrealistic, f.ex.

not all the mentioned materials can be converted,

the perforated balls can not be made hollow without filling by concrete.

a practical carrying out will be extraordinary difficult and doubtfull.

It must be concluded, that the idea in theory is possible but in no way realistic.

In relation to two-dimensional structures the idea has no sense at all. It would be completely impossible pulling balls on crossed bars.

FLOORS WITH TWO-DIMENSIONAL STRUCTURE

can not be used rationally in conventional compact design, especially in combination with supporting columns because of the high weight/thickness ratio.

If it is not wanted to provide the columns with capitals the feasibility is limited to small sections with side line about 3-5 m.

This weakness binds the whole building construction in a very close structurel module, whereby also this system becomes rigid and without flexibility.

No technic known from the one-dimensional hollow structure can be transferred to a two-dimensional hollow structure.

THE PRESENT INVENTION

solves the general problems concerning both improving shear conditions and making arbitrary flexible hollow space through a very simple technic. Hollow bodies (air bubbles) and reinforcement are integrated in a locked geometric and static unity by designing a geometric form which make the bubbles fit in the reinforcement mesh size, whereby the mutual position of the bubbles and their primary secure in horizontal direction is finally fixed.

The top of the bubbles are secondary fixed through an upper walkable mesh. The vertical secure is provided through usual binding between the two mesh. Hereby is created an internal lattice work of steel and air ready for embedding in a monolitic concreting according to usual practice. The invention also concerns the production technic regarding claim 4.

The system is at the same time untraditional and very simple, which is a consequence of two new ways of thinking, First integrating reinforcement (instead of separating) with other materials, which is the oposite of usual engineering teaching and practice. Second combining air and steel into an independent geometric and static unity, which is also a complete untraditionel and new construction.

The voids are provided through air bubbles, characterized by satisfying all 7 absolute technical conditions at the same time

1.	simple incorporation and shape	(feasibility)
2.	closed body	(water-tightness)
3.	strength	(inflexibility of contact points)
4.	reliable fixing	(against trafic and concreting)
5.	symmetry in body	(2-axis or rotation)
6.	symmetry in structure	(2-axis or rotation)
7.	no obstacles for continuous monolithic concreting	

From these criteria is developed bubbles with shapes close to ellipsoid and sphere. Regarding practic feasibility and transportation volume the bubbles are in additional developed as joint members includingvariaon possibilities.

Design by the present technic will replace 30-40% of the concrete with air. The result is a two-dimensional plane hollow floor structure characterized by having less weight, higher strength and higher stiffness than all known floor structures and in fact with unlimited bearing capacity and flexibility, which of cource also results in a better economy. The technic results in unusual profits compared with traditional compact floors,

goes for less volume of materials	is gained	in concrete	40 - 50%
		plus in steel	30 - 40%
goes for higher strength	is gained		100 - 150%
goes for larger span	is gained		up to 200%

The technic is fit for both in situ works and prefabrication of elements. There might occur minor natural variations in system and carrying out f.ex. by prefabrication and prestressing the bubbles can be fixed at the form panel on distance pieces and the reinforcement can be concentrated in the concrete ribs between the bubbles.

The invention and carrying out is more in detail explained in the following text referring to the drawings showing examples of the primary design with bubbles placed in the reinforcement mesh, and where the variation possibilities indicated in fig.6-13 are referring to the same floor thickness, and where in principle

fig.1 shows a plane view of floor structure with bubbles and supported on columns,

fig.2 shows a vertical profile of the same floor structure,

fig.3 shows components of the variable bubble,

fig.4 shows the lock between the components,

fig.5 shows a joint bubble,

fig.6 shows a plane view of floor section with bubbles of ball shape placed in every second mesh and fixed in top by binders,

fig.7 shows a vertical profile of the same section,

fig.8 shows a plane view of floor section with bubbles of ball shape placed in every third mesh and fixed in top with walkable net,

fig.9 shows a vertical profile of the same section,

fig.10 shows a plane view of floor section with bubbles of ellipsoid shape standing in every second mesh,

fig.11 shows a vertical profile of the same section,

fig.12 shows a plane view of floor section with bubbles of ellipsoid shape lying in every second mesh,

fig.13 shows a vertical profile of the same section.

There exist no substantial difference between carrying out prefabricating and in situ work, why the last will be described.
Two-way reinforcement (1) is layed out in the form (16) in quite usual way, fig.6-13, and anchored to the buttom (16). Then the bubbles (3) are layed directly on the reinforcement (1) in every second mesh (2).
The tops of the bubbles (3) are in the same way connected through an upper walkable net (12). As an alternative to the upper matress the bubbles can be tied by binders pricked into predetermined "eyes" (15) in the bubbles (3).
The two steel nets (1,12) and the bubbles (3) between them now form a stabil inflexible system in horizontal direction. The top net (12) is locked to the bottom net (1) by usual binding wires (13).
Now is completed a three-dimensional stable lattice of steel (1,12) and air (3), ready for concreting in usual way.
If wanted, the vertical binding can be carried out suitable loose, then the uplift pressure will lift the bubbles and secure full concreting of both mesh and bubbles, but the lattice it self is so elastic that complete embedding must be expected in any case.

The finished floor structure appears as a cross web construction with plane upper and underside (a three-dimensional concrete lattice).
It shall be pointed out that the work is no more time-consuming than a usual floor construction with double reinforcement.

In the following is given some calculations to illustrate the advantages of the bubble floor (o) compared with a traditional compact floor (m).

A. SAME THICKNESS

32 CM COMPACT FLOOR ctr. 32 CM BUBBLE FLOOR

Loads			compact floor (m)	bubble floor (o)
dead load	g	=	7,7	5,1 kN/m2
floor finish	g	=	0,4	0,4 -
light partitions	g	=	0,5	0,5 -
load capacity	p	=	1,5	1,5 -
design load	q = g+1,3p	=	10,6	8,0 kN/m2

Calculations are based on same statical condition in the two floors :

same effective thickness		h,e
same pressure zone	=	20% af h,e
same moment depth	=	90% - h,e
h,e is set	=	h÷3 cm

1. DIRECT PROFIT IN BEARING CAPACITY

With same support			
the load on o-floor can rise	(10,6 - 8,0) 3/4	=	2,0 kN/m2
to	1,5 + 2,0	=	3,5 -
or	100 * 2,0/1,5	=	<u>130 %</u>

2. PROFIT IN FREE SPAN

If based on bending force

M	≈	q * k * l	=	A
M,m	≈	q,m * A,m	=	10,6 A,m
M,o	≈	q,o * A,o	=	8,0 A,o
M,m / M,o	=	(10,6/8,0) * A,m/A,o	=	1,33 * A,m/A,o
M,m = M,o				
gives A,o			=	<u>1,33 * A,m</u>

If based on shear force same result.

In both cases an 33% increase of space area (≈16% in every direction).

B. SAME BEARING CAPACITY

1. IF COMPACT FLOOR SHOULD GAIN SAME CAPACITY AS BUBBLE FLOOR

bearing load			p,o =	3,5 kN/m2
the thickness must rise from 32 cm to				46 cm
corresponding to an increase of				45 %
or an extra dead load				3,5 kN/m2
Ex : thickness judged 46 cm				11,0 kN/m2
permanent load				0,9 -
working load				3,5 -
design load			q,m =	16,4 kN/m2
for load	M,m/M,o	≈ q,m / q,o	=	2,1
for floor	M,m/M,o	≈ $(h,m/h,o)^2$	=	2,1
	h,m/h,o		=	1,45
	h,m	= 32 * 1,45	=	46 cm

2. IF BUBBLE FLOOR SHOULD BE REDUCED TO SAME CAPACITY AS COMPACT FLOOR

working load			p,m =	1,5 kN/m2
the thickness could sink with 6 cm from 32 cm to				26 cm
corresponding to a reduction				20 %
or a total load reduction	7,7 - 4,2		=	3,5 kN/m2
corresponding to				45%
Ex : thickness judged	6,24 * 2/3		=	4,2 kN/m2
permanent load				0,9 -
working load				1,5 -
design load			q,o =	7,1 kN/m2
load	M,o/M,m	≈ q,o / q,m = 7,1/10,6	=	0,67
floor	M,o/M,m	≈ $(h,o/h,m)^2$	=	0,67
	h,o/h,m		=	0,82
	h,o	= 32 * 0,82	=	26 cm

C. SAME WEIGTH

32 CM BUBBLE FLOOR ctr. 21 CM COMPACT FLOOR

Loads

dead load (both)	g	=			5,1 kN/m2
floor finish	g	=			0,4 -
light partitions	g	=			0,5 -
working load	p	=			1,5 -
design load	q	=	g+1,3p	=	8,0 kN/m2

1. GAIN IN BENDING STRENGTH

for load	M,m = M,o	≈	q k l	≈	q A
for floor	M,o/M,m	≈	(h,o/h,m) *		
		=	(29 / 18) *	=	2,6

The bending strength for bubble floor is <u>160% higher</u> than the strength for compact floor.

2. GAIN IN SHEAR STRENGTH

The shear strength will also be increased with <u>more than 100%</u>, but depends besides the thickness also of the width of supporting area.

3. GAIN IN FREE SPAN

for area	M,o/M,m	≈	q A,o / q A,m	=	2,6
	A,o/A,m			=	2,6

Free span area of bubble floor is <u>160% larger</u> than free area of compact floor, or 60% in every direction.

PATENT CLAIMS

1. Plane hollow reinforced concrete floor with two-dimentional structure characterized by a construction where special hollow bodies, bubbles (3), and two-way reinforcement (1) are integrated in a locked geometric and static unity by building the bubbles (3) directly into the mesh (1), whereby the mutual position of the bubbles (3) and their primary secure in horizontal direction is finally fixed, and where the tops of bubbles are secondary fixed through an upper walkable mesh (12), or as an alternativ with usual binders, and where the vertical secure is provided through usual binding between the two mesh. Hereby is created an independent spatial stable lattice work of steel and air, which can be built up in situ or as a prefabricated lattice element, ready for embedding in a monolitic concreting.

2. Hollow reinforced concrete floor structure according to claim 1, characterized by the use of hollow closed water-resistant bodies, bubbles (3), with very thin shell of hard material as plastic (polypropylen) or the like and with the shape like an ellipsoid or similar symmetric shape.

3. Hollow reinforced concrete floor structure according to claim 1-2, characterized by the use of bubbles (3) built of two variable basic elements, bowl-shaped end pieces (4) and a cylindrical link (5) in the middle, and joint close together through snap lock (6) or the like.

4. Procedure for production of hollow floor structure according to claim 1-3, characterized by concreting around a layed out plane stable lattice of steel and air anchord to form bottom (16) and built up by a bearing two-way reinforcement in the bottom (1) in which bubbles (3) are placed in every second or every third mesh (2) and stabilized in top by an upper mesh (12) carried out as a matress with the same or half mesh size or as binders pricked into predetermined "eyes" (15) in the bubbles (3), and where the horizontal stability is provided through the bubbles settlement in the mesh and where the vertical stability is provided through usual binding (13) between the upper (12) and the bottom mesh (1).

5. Prefabricated hollow floor structures according to claim 1-4, characterized by alternativ fixing of bubbles (3) on spacers in form bottom (16) and concentrating reinforcement (1) in concrete webs (7) between the bubbles (3).

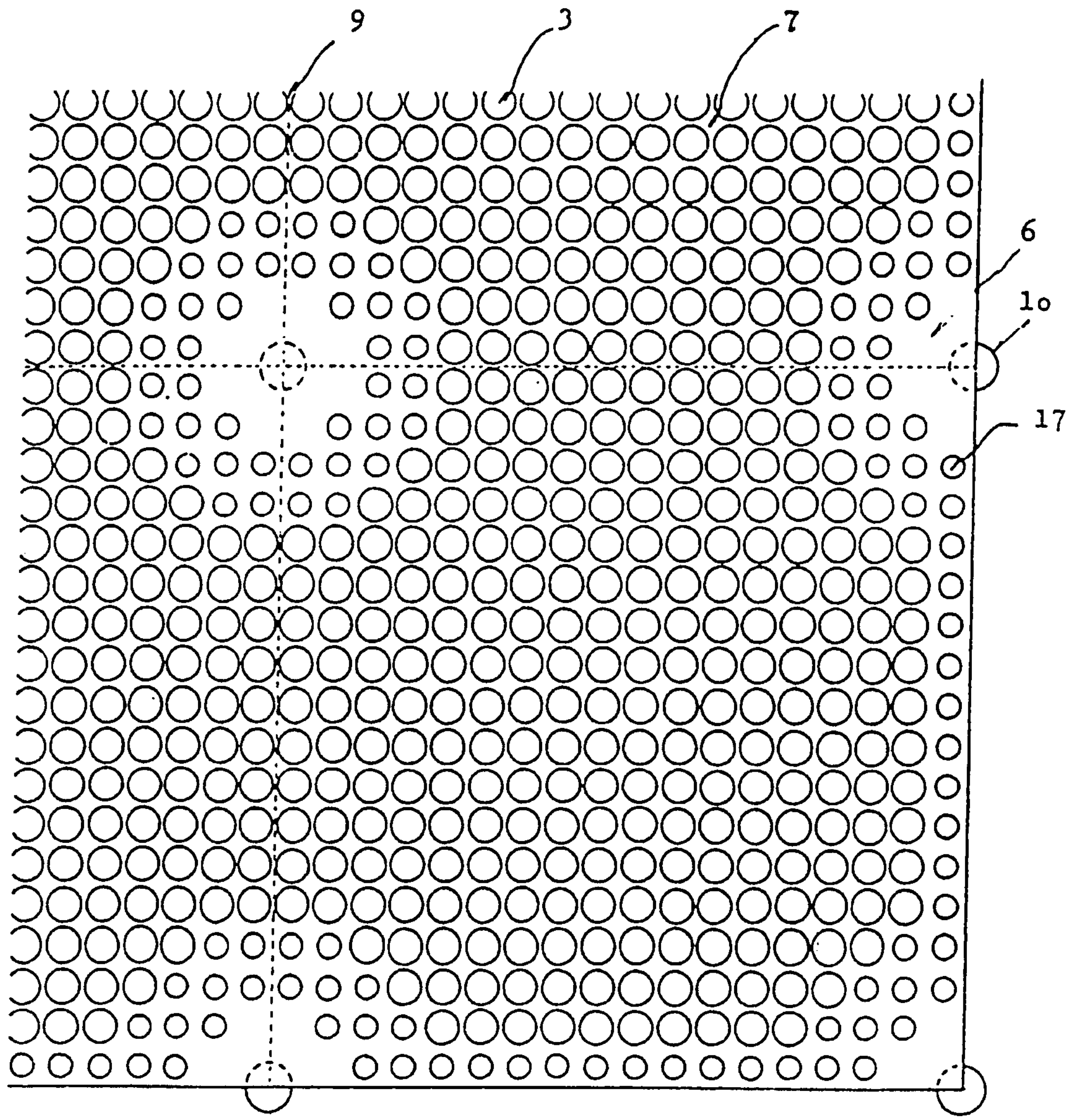

FIG. 1

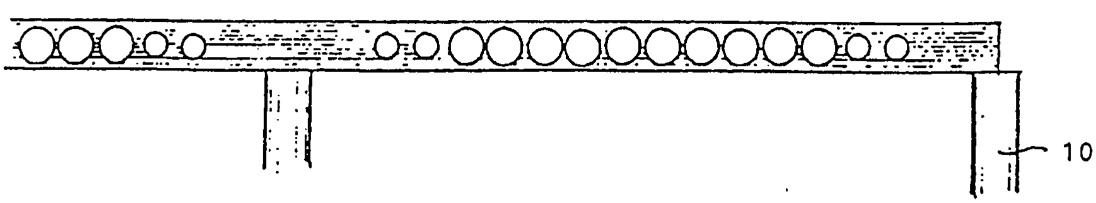

FIG. 2

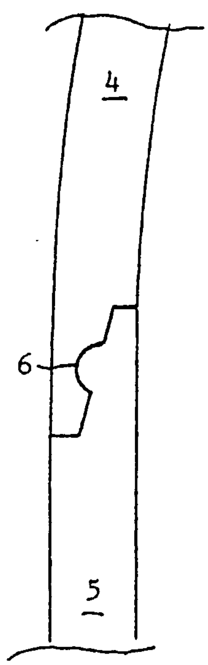

FIG. 4

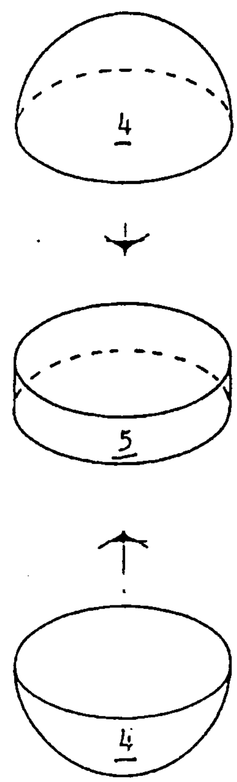

FIG. 3

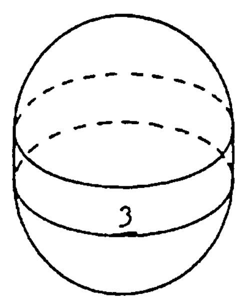

FIG. 5

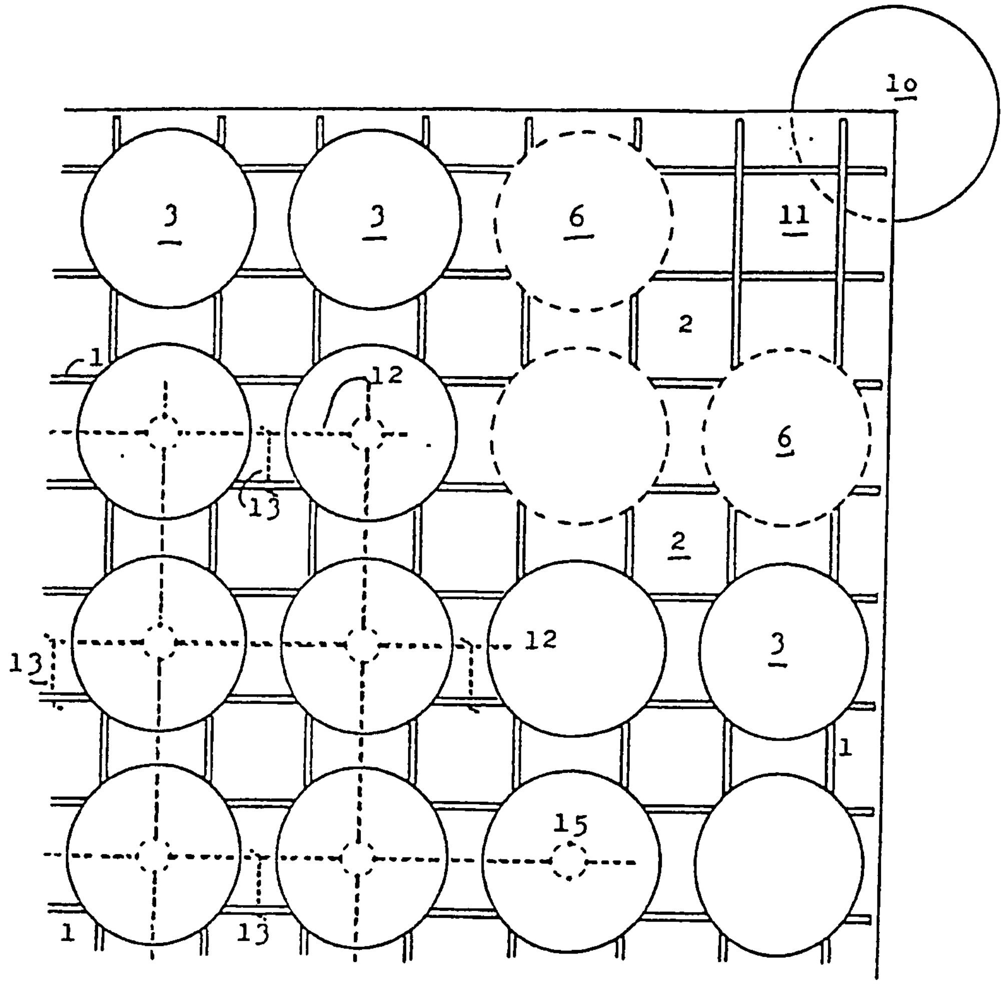

FIG. 6

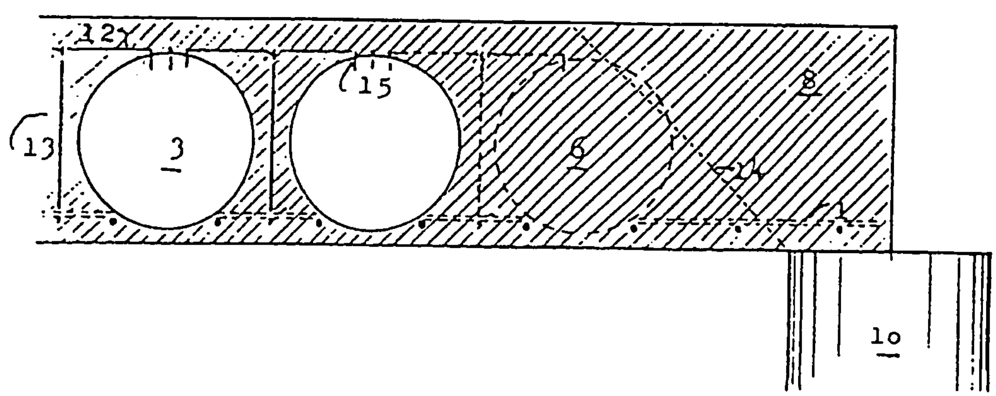

FIG. 7

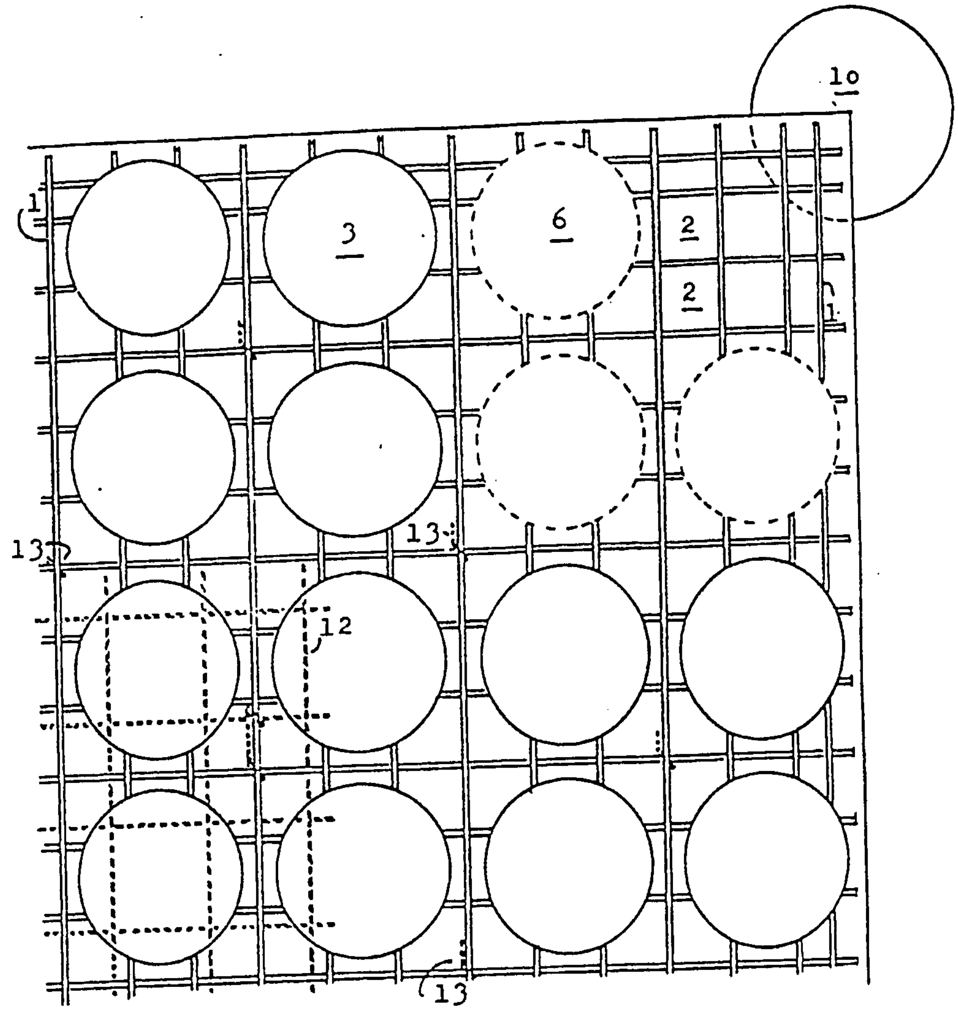

FIG. 8

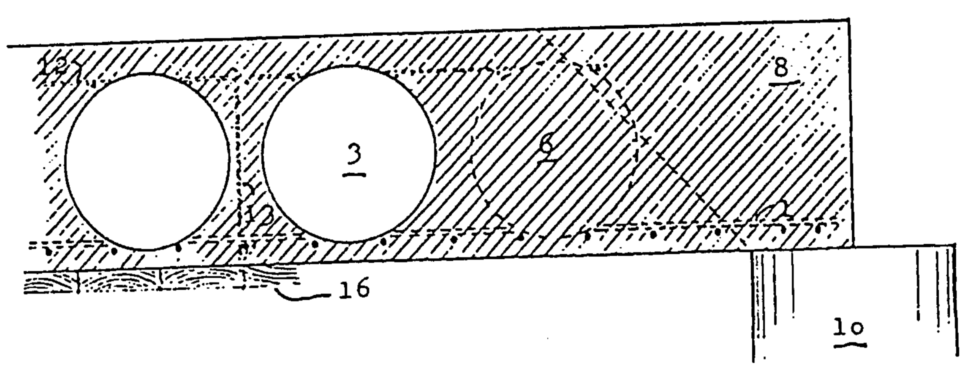

FIG. 9

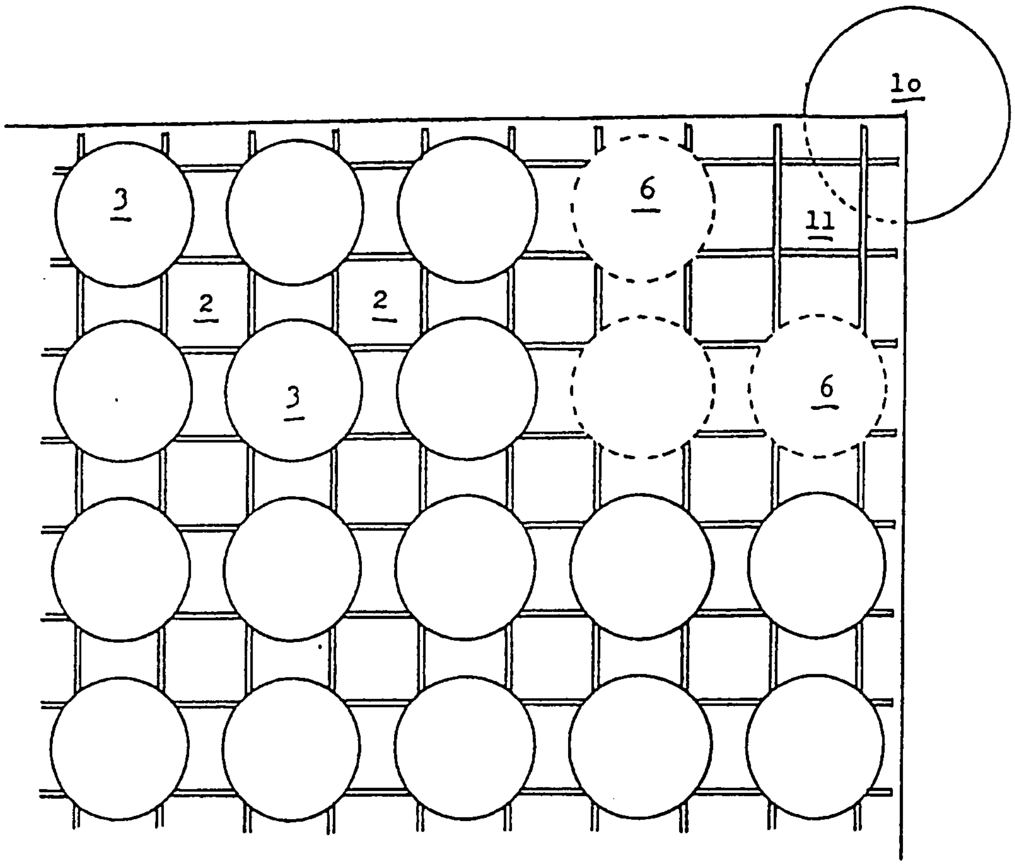

FIG. 10

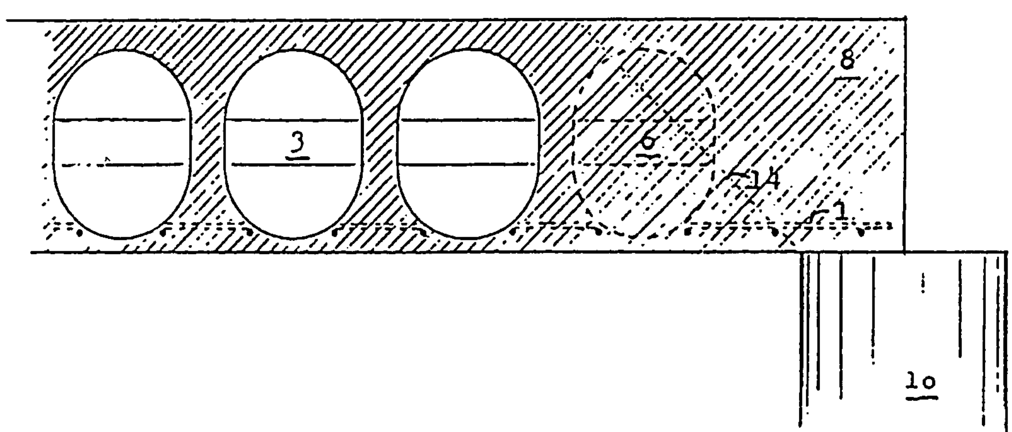

FIG. 11

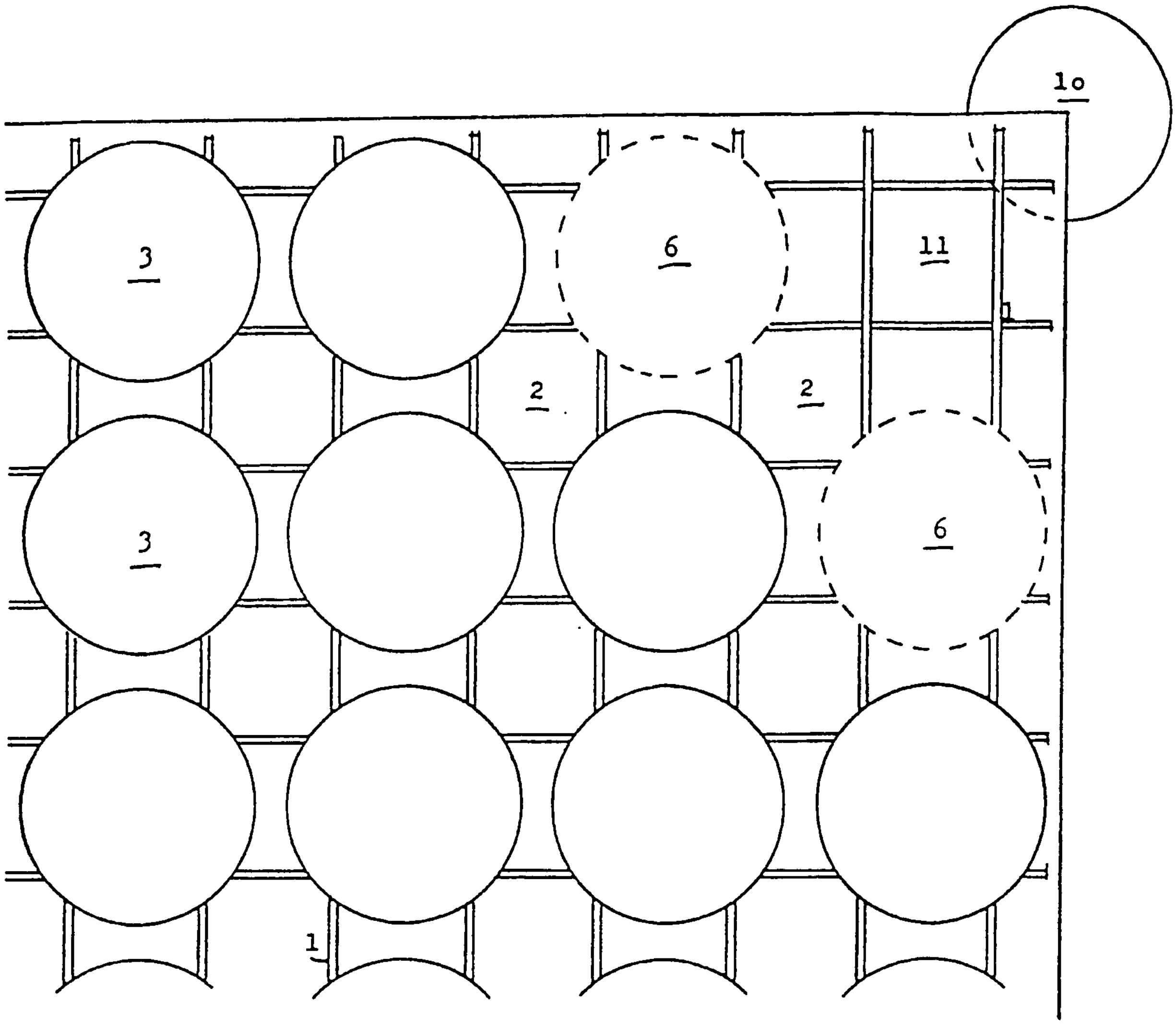

FIG. 12

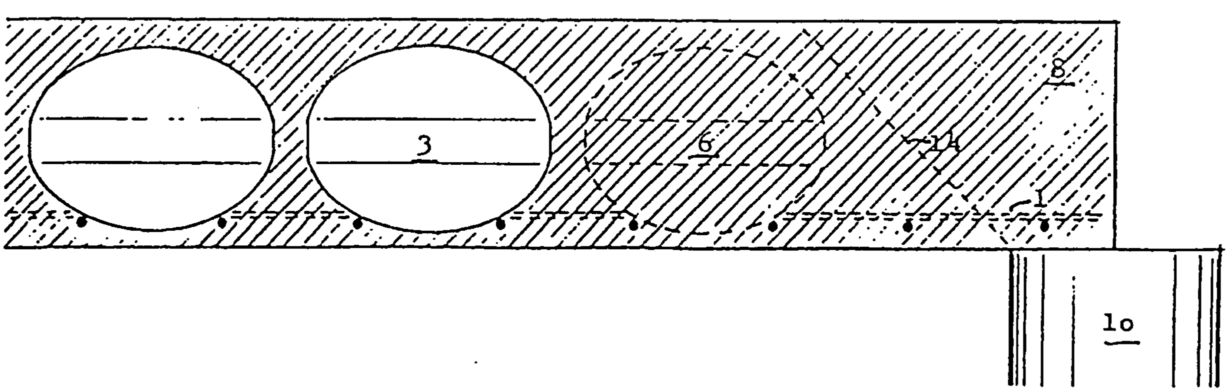

FIG. 13

INTERNATIONAL SEARCH REPORT

International Application No PCT/DK 91/00297

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: E 04 B 5/08, E 04 C 2/36

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	E 04 B; E 04 C

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
Y	DE, A1, 3006672 (RUPPMANN, O.) 10 September 1981, see page 2, line 20 - line 34 --	1,2,4
Y	US, A, 3213581 (A.J. MACCHI) 26 October 1965, see the whole document --	1,4
A	DE, A, 812833 (K. SCHRÖDER) 6 September 1951, see the whole document --	1-5
A	DE, B, 1278087 (A. FISCHER) 19 September 1968, see the whole document --	1-5
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* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
29th November 1991	1991 -12- 19
International Searching Authority	**Signature of Authorized Officer**
SWEDISH PATENT OFFICE	Örjan Nylund

Form PCT/ISA/210 (second sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.PCT/DK 91/00297

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the Swedish Patent Office EDP file on 31/10/91
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-A1- 3006672	81-09-10	NONE	
US-A- 3213581	65-10-26	NONE	
DE-A- 812833	51-09-06	NONE	
DE-B- 1278087	68-09-19	BE-A- 675337	66-05-16
		CH-A- 445082	00-00-00
		NL-A- 6602813	66-09-06